CERTIFICATE

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[Title of the Invention] LIQUID CRYSTAL DISPLAY DEVICE AND ELECTRONIC APPARATUS

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[Title of the Invention] LIQUID CRYSTAL DISPLAY DEVICE AND ELECTRONIC APPARATUS

[Claims]

[Claim 1] A liquid crystal display device having a structure in which a liquid crystal layer is sandwiched between a first and a second substrate, comprising:

a transmissive display area for performing transmissive display by passing light therethrough which is incident thereon from the outer surface of the first substrate; a reflective display area for performing reflective display by reflecting light therefrom which is incident thereon from the outer surface of the second substrate; a reflective layer disposed in the reflective display area; and a liquid-crystal-layer thickness-adjusting-layer disposed on the inner surface of at least one of the first and second substrates such that the thickness of the liquid crystal layer in the reflective display area is smaller than that of the liquid crystal layer in the transmissive area,

wherein the upper surface of an edge of the reflective layer lying in the boundary area between the transmissive display area and the reflective display area serves as a mirror reflective surface.

[Claim 2] The liquid crystal display device according to Claim 1, wherein an edge of the liquid-crystal-layer

thickness-adjusting-layer has a tapered surface in the boundary area between the reflective display area and the transmissive display area, and a part, facing the tapered surface, of the edge of the reflective layer serves as a mirror reflective surface.

[Claim 3] The liquid crystal display device according to Claim 1 or 2, wherein an area of the reflective layer, other than that whose upper surface serves as a mirror reflecting surface, is provided with light scattering means for scattering reflected light.

[Claim 4] The liquid crystal display device according to any one of Claims 1 to 3, further comprising a color filter on either one of the first and second substrates.

[Claim 5] An electronic apparatus comprising the liquid crystal display device according to any one of Claims 1 to 4.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to liquid crystal display devices and electronic apparatuses, and more specifically, it relates to a multi-gap-type transflective liquid crystal display device in which the thicknesses of a liquid crystal layer in a transmissive display area and a reflective display area are optimized.

[0002]

[Description of the Related Art]

So-called transflective liquid crystal display devices combining two types of reflective display and transmissive display offer clear display even in a dark environment, while reducing power consumption, by selecting either a reflective mode or a transmissive mode in accordance with the level of brightness of the ambient light.

[0003]

As a transflective liquid crystal display device of this type, a liquid crystal display device is proposed, having a structure in which a liquid crystal layer is sandwiched between upper and lower substrates, and a reflective film having slits passing light therethrough and formed in a metal film composed of, for example, aluminum is disposed on the inner surface of the lower substrate such that the reflective film serves as a transflective film. In this case, in the reflective mode, external light incident on the upper substrate is reflected from the reflective film disposed on the inner surface of the lower substrate after passing through the liquid crystal layer; again passes through the liquid crystal layer; is emitted from the upper substrate; and thus contributes to performing display. Meantime, in the transmissive mode, light emitted from a backlight and incident on the lower substrate is emitted outside from the upper substrate after passing through the

slits of the reflective film and then the liquid crystal layer; and thus contributes to performing display. Accordingly, in this case, each area having the corresponding slit of the reflective film formed therein serves as a transmissive display area and another area having no slit of the reflective film formed therein serves as a reflective display area.

[0004]

In the transflective liquid crystal display device, since a change in polarization states is a function of the product (i.e., retardation $\Delta n \cdot d$) of a degree Δn of the anisotropy of refractive index of liquid crystal and a thickness d of a liquid crystal layer, highly visible display can be performed by optimizing this value. Meanwhile, since reflective display light passes through the liquid crystal layer twice in both directions while transmissive display light passes through the liquid crystal layer only once, it is difficult to optimize the retardation $\Delta n \cdot d$ for both the transmissive display light and the reflective display light. As a result, when the thickness of the liquid crystal layer is set so as to provide highly visible display in the reflective mode, the display in the transmissive mode is sacrificed. Conversely, when the thickness of the liquid crystal layer is set so as to provide highly visible display in the transmissive mode, the

display in the reflective mode is sacrificed.

[0005]

With this problem in mind, a structure in which the thickness of a liquid crystal layer in the reflective display area is smaller than that in the transmissive display area is disclosed in Japanese Unexamined Patent Application Publication No. 11-242226. Such a structure is called a multi-gap type and is achieved, for example, by providing a liquid-crystal-layer thickness-adjusting-layer, having apertures perforated so as to correspond to the respective transmissive display areas, below a transparent electrode of the lower substrate and above the reflective film. That is, since the liquid crystal layer in the transmissive display area is thicker than in the reflective display area by an amount of the thickness of the liquid-crystal-layer thickness-adjusting-layer, the retardation $\Delta n \cdot d$ can be optimized for both the transmissive display light and the reflective display light. When the liquid-crystal-layer thickness-adjusting-layer is used in order to adjust the thickness of the liquid crystal layer, the liquid-crystal-layer thickness-adjusting-layer is required to have a considerable thickness. To form such a thick layer, for example, a photosensitive resin is used.

[0006]

[Problems to be Solved by the Invention]

Unfortunately, in the foregoing multi-gap-type transflective liquid crystal display device, when the liquid-crystal-layer thickness-adjusting-layer having apertures is formed with a photosensitive resin or the like, although a photolithography technique is used, the edge of each aperture of the liquid-crystal-layer thickness-adjusting-layer, that is, the boundary area between the transmissive display area and the reflective display area, ends up a shape having a tapered surface, due to exposure accuracy in the above forming step, sand-etching in a development step, or the like. As a result, in the boundary area between the transmissive display area and the reflective display area, the thickness of the liquid crystal layer varies continuously, and accordingly the retardation $\Delta n \cdot d$ of the same also varies continuously, whereby the retardation $\Delta n \cdot d$ results in having an inappropriate value for both the transmissive display light and the reflective display light in this area. Also, the initial alignment state of liquid crystal molecules making up the liquid crystal layer is defined by alignment films disposed on the upper and lower substrates, and aligning regulatory forces of the alignment films act obliquely on them lying in the region in which the tapered surface is disposed, whereby the alignment of the liquid crystal molecules is adversely affected in this area.

[0007]

Even when the edge of the aperture of the thickness-adjusting-layer, that is, the boundary area between the transmissive display area and the reflective display area is formed so as to have a step perpendicular to the surfaces of the substrates instead of having a tapered surface, the alignment of the liquid crystal molecules is adversely affected in the boundary area between the transmissive display area and the reflective display area.

[0008]

In the known multi-gap-type transflective liquid crystal display device, when it is designed, for example, so as to function in a normally white mode, although it is expected to perform black display upon application of a voltage on the liquid crystal layer, the above-mentioned problem actually causes leakage of light in the boundary area between the transmissive display area and the reflective display area, thereby leading to deteriorated contrast.

[0009]

The present invention has been made in order to solve the above-described problem. Accordingly, it is an object of the present invention to provide a transflective liquid crystal display device which performs high-contrast display for both the transmissive display and the reflective display.

Also, it is another object of the present invention to provide an electronic apparatus equipped with the foregoing liquid crystal display device, for performing high-quality display.

[0010]

[Means for Solving the Problems]

In order to achieve the above-mentioned objects, a liquid crystal display device according to the present invention, having a structure in which a liquid crystal layer is sandwiched between a first and a second substrate, includes a transmissive display area for performing transmissive display by passing light therethrough which is incident thereon from the outer surface of the first substrate; a reflective display area for performing reflective display by reflecting light therefrom which is incident thereon from the outer surface of the second substrate; a reflective layer disposed in the reflective display area; and a liquid-crystal-layer thickness-adjusting-layer, disposed on the inner surface of at least one of the first and second substrates, such that the thickness of the liquid crystal layer in the reflective display area is smaller than that of the liquid crystal layer in the transmissive area. The upper surface of an edge of the reflective layer lying in the boundary area between the transmissive display area and the reflective

display area serves as a mirror reflective surface. The term "boundary area" in this specification means an area formed by a boundary defined by the edge of the reflective layer and lying between the reflective display area and the transmissive display area, and by an edge of the reflective display area next to the above boundary.

[0011]

The main feature of the liquid crystal display device according to the present invention lies in that the upper surface of the edge of the reflective layer lying in the boundary area between the transmissive display area and the reflective display area serves as a mirror reflective surface. With this feature, although the boundary area is regarded as a part of the reflective display area because of having a part of the reflective layer formed therein, the upper surface of the above-mentioned part serves as a mirror reflective surface, whereby external light coming from the outer surface of the second substrate is regularly reflected in this area. In the meantime, when a user operates the liquid crystal display device in the usual way, since the user does not see the liquid crystal display device from the regularly reflecting direction of external light such as sunlight or illuminating light, light reflected from the mirror reflective surface at the time of performing black display does not enter the eyes of the user, whereby

contrast of the reflective display is not deteriorated. In addition, since the reflective layer is present in the boundary area, the transmissive display is not adversely affected. Accordingly, in the boundary area between the reflective display area and the transmissive display area, even when the thickness of the liquid-crystal-layer thickness-adjusting-layer varies continuously and accordingly the retardation Δn·

d in the boundary area varies continuously, or even when the alignment of liquid crystal molecules is adversely affected, high-contrast display for both the transmissive display and the reflective display can be achieved.

[0012]

The liquid crystal display device may have a structure in which an edge of the liquid-crystal-layer thickness-adjusting-layer has a tapered surface in the boundary area between the reflective display area and the transmissive display area, and a part, facing the tapered surface, of the edge of the reflective layer serves as a mirror reflective surface.

[0013]

When the thickness-adjusting layer is formed of a photosensitive resin as described above, the edge of the aperture of the liquid-crystal-layer thickness-adjusting-layer, that is, the boundary area between the transmissive

display area and the reflective display area, sometimes serves as a tapered surface depending on the situation of a photolithography step. In this case, as the thickness of the liquid crystal layer varies continuously, the retardation $\Delta n \cdot d$ varies continuously. Even in such a case, with the above structure, factors deteriorating contrast of the reflective display are prevented from occurring, thereby achieving high-contrast display for both the transmissive display and the reflective display.

[0014]

Furthermore, an area of the reflective layer, other than that whose upper surface serves as a mirror reflective surface, is preferably provided with light-scattering means for scattering reflected light.

[0015]

With this structure, since the light scattering means is provided on the area other than that whose upper surface is formed so as to serve as a mirror reflective surface, that is, provided in an area which contributes effectively to the reflective display, a sufficient amount of the reflected light which is scattered and enters the eyes of the user can be kept, thereby achieving brighter reflective display.

[0016]

The liquid crystal display device may further include a

color filter on either one of the first and second substrates.

[0017]

With this structure, a transflective liquid crystal display device performing color display can be achieved.

[0018]

An electronic apparatus according to the present invention includes the liquid crystal display device according to the present invention. With this structure, an electronic apparatus allowing selection between transmissive display and reflective display and performing high quality color display can be provided.

[0019]

[Description of the Embodiments]

[First Embodiment]

A first embodiment of the present invention will be described with reference to Figs. 1 to 5.

In this embodiment, an active-matrix, transflective liquid crystal display device of a reflector built-in type in which a pixel electrode on an element substrate serves also as a reflector will be described by way of example. Fig. 1 is a plan view of a liquid crystal display device according to the present embodiment and its components, viewed from a counter substrate, and Fig. 2 is a sectional view taken along the line H-H' indicated in Fig. 1. Fig. 3

is an equivalent circuit diagram of a variety of elements, wiring lines, and so forth of a plurality of pixels formed in a matrix manner in an image display area of an electro-optical device (i.e., the liquid crystal display device). Meanwhile, in each figure which will be referred in the following description, each of the layers and the components has a respectively different reduced scale so as to be easily seen in the figure.

[0020]

[General Structure of Liquid Crystal Display Device]

As shown in Figs. 1 and 2, a liquid crystal display device 100 according to the present embodiment has a TFT array substrate 10 and a counter substrate 20 bonded to each other by a sealant 52, and a liquid crystal layer 50 filled in the area defined by the sealant 52. A light shielding film (peripheral partition) 53 composed of a light shielding material is formed inside the forming area of the sealant 52. Outside the sealant 52, a data-line drive circuit 201 and external-circuit packing terminals 202 are formed along a side of the TFT array substrate 10, and scanning-line drive circuits 204 are formed along two sides of the same next to the foregoing side. Along the remaining side of the TFT array substrate 10, a plurality of wire lines 205 for connecting the scanning-line drive circuits 204 formed along both sides of an image display area is disposed. Also, the

counter substrate 20 has substrate-interconnecting conductive materials 206 disposed at its corners for electrically connecting the TFT array substrate 10 with the counter substrate 20.

[0021]

Meantime, instead of forming the data-line drive circuit 201 and the scanning-line drive circuits 204 on the TFT array substrate 10, for example, a TAB (tape automated bonding) substrate having a drive LSI mounted thereon may be electrically and mechanically connected with a group of terminals formed around the TFT array substrate 10 via an anisotropic conductive film. Meanwhile, in the liquid crystal display device 100, although retardation films, polarizers, and so forth are disposed in respectively predetermined orientations depending on the type of used liquid crystal, that is, in accordance with an operation mode such as a TN (twisted nematic) mode or an STN (super twisted nematic) mode, and also depending on whether it is operated in a normally white mode or a normally black mode, these components are not shown in the figures.

[0022]

In the image display area of the liquid crystal display device 100 having the above-mentioned structure, as shown in Fig. 3, a plurality of dots 100a are disposed in a matrix array. In addition, a pixel-switching TFT 30 is formed at

each dot 100a, and data lines 6a for feeding pixel signals S1, S2, ---, Sn are electrically connected to sources of the corresponding TFTs 30. The pixel signals S1, S2, ---, Sn to be written to the data lines 6a may be fed in a line-sequential manner in that order, or may be fed to the data lines 6a group by group, each including a plurality of the adjacent data lines 6a. Also, a scanning line 3a is electrically connected to a gate of each TFT 30, and scanning signals G1, G2, ---, Gm having a pulse waveform are applied to the scanning lines 3a with a predetermined timing in a line-sequential manner in that order. Pixel electrodes 9 are electrically connected to drains of the respective TFTs 30, and, by holding the TFTs 30 serving as switching elements in an on-state for a predetermined time period, the pixel signals S1, S2, ---, Sn fed from the data lines 6a are written into the corresponding pixels with a predetermined timing. The pixel signals S1, S2, ---, Sn at a predetermined level, written into the liquid crystal via the pixel electrodes 9 as described above, are held between a counter electrode 21 of the counter substrate 20 shown in Fig. 2 and the corresponding pixel electrodes 9 for a predetermined time period. Also, in order to prevent the leakage of the held pixel signals S1, S2, ---, Sn, storage capacitors 60 are additionally formed in parallel with the corresponding liquid crystal capacitors formed between the

pixel electrodes 9 and the counter electrode 21. Capacitor lines 3b make the corresponding storage capacitors 60.

[0023]

[Detailed Structure of One Dot]

Fig. 4 is a plan view of the general structure of one of the dots 100a forming an image of the liquid crystal display device 100 according to the present embodiment. Fig. 5 is a sectional view taken along the line A-A' indicated in Fig. 4. Although wire lines such as the data line 6a and the scanning line 3a, the TFT 30, and the like are actually formed on the TFT array substrate 10, these wire lines, the TFT, and the like are not shown in Fig. 4. The liquid crystal display device 100 according to the present embodiment aims at performing color display, and one pixel is made up by three adjacent dots for R (red), G (green), and B (blue).

[0024]

As shown in Fig. 4, an area partitioned by a light shielding film (black matrix) 40 formed on the counter substrate 20 in a latticed array makes up one dot 100a. Meanwhile, a reflective electrode 42 serving as a reflector and a part of the pixel electrode is disposed on the TFT array substrate 10. The reflective electrode 42 has an aperture 42a at the center thereof and a transparent electrode 43 disposed in the aperture 42a. The pixel

electrode 9 of one dot is made up by the reflective electrode 42 and the transparent electrode 43. With this structure, the aperture 42a of the reflective electrode 42 serves as a transmissive display area T for performing transmissive display by using light emitted from a backlight, which will be described later, and the area having the reflective electrode 42 lying therein makes up a reflective display area R for performing reflective display by using external light incident on the counter substrate 20. Although reflected light is scattered at and emitted from most parts of the reflective display area R, as will be described later, the periphery of the aperture 42a lying in a boundary area K of the reflective display area R with the transmissive display area T serves as a mirror reflective surface from which light is regularly reflected.

[0025]

As shown in Fig. 5, the liquid crystal display device 100 according to the present embodiment has a basic structure in which a liquid crystal layer 50 is sandwiched between the TFT array substrate 10 and the counter substrate 20 which are composed of transparent glass or the like and which are respectively disposed above and below so as to oppose each other. Also, a backlight 60 including a light source 61, a light guiding plate 62, and the like is disposed at the side close to the outer surface of the TFT

array substrate 10. A retardation film 12 and a polarizer 13 are disposed at the side close to the outer surface of the counter substrate 20 (at a side close to a user), and a retardation film 14 and a polarizer 15 are disposed at the side close to the outer surface of the TFT array substrate 10 (at a side close to the backlight). The polarizers 13 and 15 respectively allow only linearly polarized light traveling in one direction, of external light coming from above and that of the backlight coming from below to be transmitted therethrough. Also, the retardation films 12 and 14 transform the linearly polarized light respectively transmitted through the polarizers 13 and 15 into circularly polarized light (including elliptically polarized light). Accordingly, the polarizers 13 and 15 together with the retardation films 12 and 14 serve as circularly-polarized-light input means.

[0026]

At the side close to the inner surface of the counter substrate 20, a color filter 45 having R, G, and B coloring layers is disposed, and a liquid-crystal-layer thickness-adjusting-layer (insulating layer) 46 for forming a thick layer area and a thin layer area of the liquid crystal layer 50 is formed on the color filter 45 so as to corresponding to the reflective display area R. More particularly, with the liquid-crystal-layer thickness-adjusting-layer 46 being

formed, the thickness of the liquid crystal layer 50 in the reflective display area R is smaller than that in the transmissive display area T. Also, corresponding to the transmissive display area T, the liquid-crystal-layer thickness-adjusting-layer 46 has a depression formed between adjacent projections thereof, and, in the boundary area between the reflective display area R and the transmissive display area T, it has a tapered surface 46a at an example angle of 10 to 50 degrees with respect to the bottom of the depression. Accordingly, the thickness of the liquid-crystal-layer thickness-adjusting-layer 46 varies continuously in the boundary area K, and thus the thick of the liquid crystal layer 50 also varies continuously in the boundary area K. The liquid-crystal-layer thickness-adjusting-layer 46 is made from, for example, a transmissive insulating material such as an acrylic resin.

[0027]

In this embodiment, the color filter 45 is uniformly disposed both in the transmissive display area T and the reflective display area R. Instead of this structure, color filters may be differently prepared for the transmissive display area T and the reflective display area R such that the spectral characteristics of a transmissive-display color filter and a reflective-display color filter are different from each other and such that the transmissive-display color

filter has higher color purity than that of the reflective-display color filter. With this structure, a balance of color shading between the transmissive display area T and the reflective display area R can be adjusted.

[0028]

Also, the counter substrate 20 has a counter electrode 21, which is made from a transparent conductive film composed of ITO or the like, formed on the entire inner surface thereof so as to cover the color filter 45 and the liquid-crystal-layer thickness-adjusting-layer 46, and also the counter electrode 21 has an alignment film 22 formed thereon, made from a polymeric material film composed of, for example, polyimide and being subjected to a predetermined rubbing treatment.

[0029]

Meanwhile, at the side close to the inner surface of the TFT array substrate 10, the reflective electrode 42 made from a highly reflective metal film or the like such as aluminum or silver and having the aperture 42a is formed, and the transparent electrode 43 made from a transparent conductive film composed of ITO or the like is disposed in the aperture 42a of the reflective electrode 42. As described above, the area having the transparent electrode 43 formed therein corresponds to the transmissive display area T, and the area having the reflective electrode 42

formed therein corresponds to the reflective display area R. The reflective electrode 42 and the transparent electrode 43 have an alignment film 23 formed thereon, made from a polymeric material film composed of, for example, polyimide and being subjected to a predetermined rubbing treatment in the same fashion as in the counter substrate 20.

[0030]

Also, in an area of the upper surface of a main substrate 10a of the TFT array substrate 10, corresponding to a flat surface of the liquid-crystal-layer thickness-adjusting-layer 46 and excluding the boundary area K between the transmissive display area T and the reflective display area R, projections 25 composed of, for example, an acrylic resin are formed. Since the reflective electrode 42 is formed so as to cover the projections 25, the reflective electrode 42 has projections and depressions on the upper surface thereof, having a profile of reflecting the outer shape of the projections 25. With this structure, light incident on this area is scattered thereat upon reflection and is emitted therefrom. Contrary, since the boundary area K between the transmissive display area T and the reflective display area R has no projections 25, the upper surface of the reflective electrode 42 in the this area serves as a mirror reflective surface 42m, thereby allowing incident light to be emitted only in the regularly reflecting

direction.

[0031]

In the general display configuration of the transflective liquid crystal display device, while incident light passes through the liquid crystal layer twice in the reflective display area, light emitted from the backlight passes through the liquid crystal layer only once in the transmissive display area. Taking a retardation of the liquid crystal layer into account, when the alignment of the liquid crystal is controlled by applying the same voltage for the reflective display and the transmissive display, the transmittances of the liquid crystal for the above display states are different from each other due to the different retardations of the liquid crystal. Meanwhile, with the structure of the liquid crystal display device according to the present embodiment, since the liquid-crystal-layer thickness-adjusting-layer 46 is disposed in the reflective display area R, the thickness of the liquid crystal layer 50 in the transmissive display area T is greater than that in the reflective display area R, whereby the travel distances of light passing through the liquid crystal layer 50 in the reflective display area R and in the transmissive display area T can be arranged so as to be equal to each other. As a result, retardations $\Delta n \cdot d$ in the reflective display area R and the transmissive display area T are equalized, thereby

leading to bright, high-contrast display for both the reflective display and the transmissive display.

[0032]

Whereas, in the boundary area K between the transmissive display area T and the reflective display area R, since the liquid-crystal-layer thickness-adjusting-layer 46 has the tapered surface 46a, the thickness of the liquid crystal layer 50 varies continuously; as a result, the retardation $\Delta n \cdot d$ thereof also varies continuously, whereby the retardation $\Delta n \cdot d$ ends up as having an inappropriate value for both the transmissive display light and the reflective display light in the boundary area. Although the initial alignment of liquid crystal molecules making up the liquid crystal layer 50 is defined by the alignment films 22 and 23, since an aligning regulatory force of the alignment film 23 acts obliquely on the liquid crystal molecules lying in a region having the tapered surface 46a disposed therein, the alignment of the liquid crystal molecules is adversely affected in this region.

[0033]

On the contrary, in this embodiment, since the reflective electrode 42 has the mirror reflective surface 42m on the upper surface thereof corresponding to the boundary area K between the transmissive display area T and the reflective display area R, external light coming from

the counter substrate 20 is regularly reflected in this area. However, when a user operates the liquid crystal display device in the usual way, since the user does not see the liquid crystal display device 100 from the regularly reflecting direction of external light such as sunlight or illuminating light but sees it from substantially the front (the normal), light reflected from the mirror reflective surface 42m at the time of performing black display does not enter the eyes of the user, whereby contrast of the reflective display is prevented from being deteriorated. In addition, since the reflective electrode 42 is present in the boundary area K, the transmissive display is not adversely affected. Meanwhile, since the reflective electrode 42 has the projections and depressions on the upper surface thereof in the most part of the reflective display area R in which the boundary area K is absent, reflected light is scattered thereat, thereby leading to bright, visible reflective display. Accordingly, in the boundary area K between the reflective display area R and the transmissive display area T, although the thickness of the liquid-crystal-layer thickness-adjusting-layer 46 varies continuously and the retardation $\Delta n \cdot d$ varies continuously, high-contrast display for both the transmissive display and the reflective display can be achieved even when the alignment of liquid crystal molecules is adversely affected.

[0034]

According to the study of the inventor, for example, when the boundary area (the area in which the liquid-crystal-layer thickness-adjusting-layer has a tapered surface) has a transparent electrode disposed therein, that is, the boundary area is arranged so as to serve as the transmissive display area, the contrasts of the transmissive display and the reflective display are respectively 30 and 50. Meanwhile, when the boundary area has a reflective electrode disposed therein and also a scattering layer having projections and depressions formed in the same fashion as in the remaining of the reflective display area, the contrasts of the transmissive display and the reflective display are respectively 100 and 15. As opposed to the above results, when the boundary area has a reflective electrode disposed therein so as to serve as a mirror reflective surface in the same fashion as in present embodiment, the contrasts of the transmissive display and the reflective display are respectively 100 and 50, thereby proving that high-contrast display for both the transmissive display and the reflective display can be achieved.

[0035]

[Second Embodiment]

Referring now to Fig. 6, a second embodiment of the present invention will be described.

Although a liquid crystal display device according to the present embodiment has the same basic structure as that in the first embodiment, since the color filter is disposed close to the lower substrate, the upper substrate serves as an element substrate; accordingly, the liquid crystal display device has a difference only in its sectional structure from that of the first embodiment. Hence, only the sectional structure of the liquid crystal display device will be described, referring to Fig. 6 corresponding to Fig. 5 in the first embodiment. Also, common parts in Fig. 6 as in Fig. 5 are denoted by the same reference numerals, and the description of the common parts will be omitted.

[0036]

As shown in Fig. 6, in a liquid crystal display device 101 according to the present embodiment, a lower substrate 1 has a reflective film 70 having an aperture 70a formed on the inner surface thereof, and the color filter 45 is formed on the inner surface of a main substrate 1a including the reflective film 70. In this embodiment, the reflective film 70 does not serve as the pixel electrode 9; the area having the reflective film 70 lying therein makes up the reflective display area R; and the area having the aperture 70a of the reflective film 70 lying therein makes up the transmissive display area T. The liquid-crystal-layer thickness-adjusting-layer 46 is formed on the color filter 45 in the

reflective display area R and has the pixel electrode 9 made from a transparent conductive film composed of ITO or the like and the alignment film 23 formed on the entire surface thereof. Meanwhile, an upper substrate 2 opposing the lower substrate 1 and having the liquid crystal layer 50 interposed therebetween has the counter electrode 21 and the alignment film 22 formed on the inner surface thereof in that order. Also, in this embodiment, although the reflective film 70 has projections and depressions formed on the upper surface thereof due to the profile of the projections 25 formed on the main substrate 1a of the lower substrate 1, it has no projections and depressions formed in the boundary area K between the transmissive display area T and the reflective display area R, corresponding to the tapered surface 46a of the liquid-crystal-layer thickness-adjusting-layer 46, thus serving as a mirror reflective surface 70m.

[0037]

Also, in the liquid crystal display device 101 according to the present embodiment, since the upper surface of the reflective film 70 lying in the boundary area K between the transmissive display area T and the reflective display area R serves as the mirror reflective surface 70m, and thus, regular reflection occurs in the area, the contrast of the reflective display is not deteriorated even

when this area is included in the reflective display area R. As a result, the same advantage of high-contrast display for both the transmissive display and the reflective display as in the first embodiment can be obtained.

[0038]

[Electronic Apparatus]

Example electronic apparatuses equipped with the liquid crystal display device according to any one of the foregoing embodiments will be described.

Fig. 7 is a perspective view of an example portable phone. In Fig. 7, reference numerals 1000 and 1001 respectively represent a main body of the portable phone and a liquid crystal display unit including any one of the foregoing liquid crystal display devices.

[0039]

Fig. 8 is a perspective view of an example wristwatch-type electronic apparatus. In Fig. 8, reference numerals 1100 and 1101 respectively represent a main body of a watch and a liquid crystal display unit including any one of the foregoing liquid crystal display devices.

[0040]

Fig. 9 is a perspective view of an example portable information processor such as a word processor or a personal computer. In Fig. 9, reference numerals 1200, 1202, 1204, and 1206 respectively represent an information processor, an

input unit such as a keyboard, a main body of the information processor, and a liquid crystal display unit including any one of the foregoing liquid crystal display devices.

[0041]

Each of the electronic apparatuses shown in Figs. 7 to 9 is equipped with the corresponding liquid crystal display unit including any one of the liquid crystal display devices according to the foregoing embodiments, thereby achieving an electronic apparatus which is equipped with a display unit featuring bright, high-contrast display in a variety of environments and which thus performs high-quality color display. Also, an electronic apparatus equipped with a display unit which rarely performs defective display even in the boundary area between the reflective display area and the transmissive display area can be achieved.

[0042]

[Advantages]

As described above in detail, in each of the liquid crystal display devices according to the present invention, since the reflective film has a mirror reflective surface on the upper surface thereof in the boundary area between the transmissive display area and the reflective display area, and regular reflection occurs in the boundary area, contrast of the reflective display is not deteriorated even when the

boundary area is included in the reflective display area, whereby high-contrast display for both the transmissive display and the reflective display can be achieved.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a plan view of a liquid crystal display device according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a sectional view taken along the line H-H' indicated in Fig. 1.

[Fig. 3] Fig. 3 is an equivalent circuit diagram of a variety of elements, wire lines, and so forth of a plurality of pixels formed in a matrix manner in an image display area of the liquid crystal display device shown in Fig. 1.

[Fig. 4] Fig. 4 is a plan view of the general structure of one dot of the liquid crystal display device shown in Fig. 1.

[Fig. 5] Fig. 5 is a sectional view taken along the line A-A' indicated in Fig. 4.

[Fig. 6] Fig. 6 is a sectional view of a liquid crystal display device according to a second embodiment of the present invention.

[Fig. 7] Fig. 7 is a perspective view of an example electronic apparatus equipped with any one of the liquid crystal display devices.

[Fig. 8] Fig. 8 is a perspective view of another example

electronic apparatus equipped with any one of the liquid crystal display devices.

[Fig. 9] Fig. 9 is a perspective view of another example electronic apparatus equipped with any one of the liquid crystal display devices.

[Reference Numerals]

9: pixel electrode

10: TFT array substrate

20: counter substrate

25: projections

42: reflective electrode

42a: aperture (of the reflective electrode)

42m, 70m: mirror reflective surfaces

43: transparent electrode

45: color filter

46: liquid-crystal-layer thickness-adjusting-layer

46a: tapered surface (of the liquid-crystal-layer thickness-adjusting-layer)

50: liquid crystal layer

70: reflective film

R: reflective display area

T: transmissive display area

K: boundary

[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a transflective liquid crystal display device which performs high-contrast display for both the transmissive display and the reflective display.

[Solving Means] A liquid crystal display device 100 according to the present invention has a transmissive display area T and a reflective display area R; has a reflective electrode 42 disposed in the reflective display area R; and also has a liquid-crystal-layer thickness-adjusting-layer 46 disposed therein for making the thickness of a liquid crystal layer 50 in the reflective display area R smaller than that in the transmissive display area T. Also, the upper surface of an edge of the reflective electrode 42, lying in a boundary area K between the transmissive display area T and the reflective display area R, is arranged so as to serve as a mirror reflective surface 42m.

[Selected Figure] Fig. 5

FIG. 1

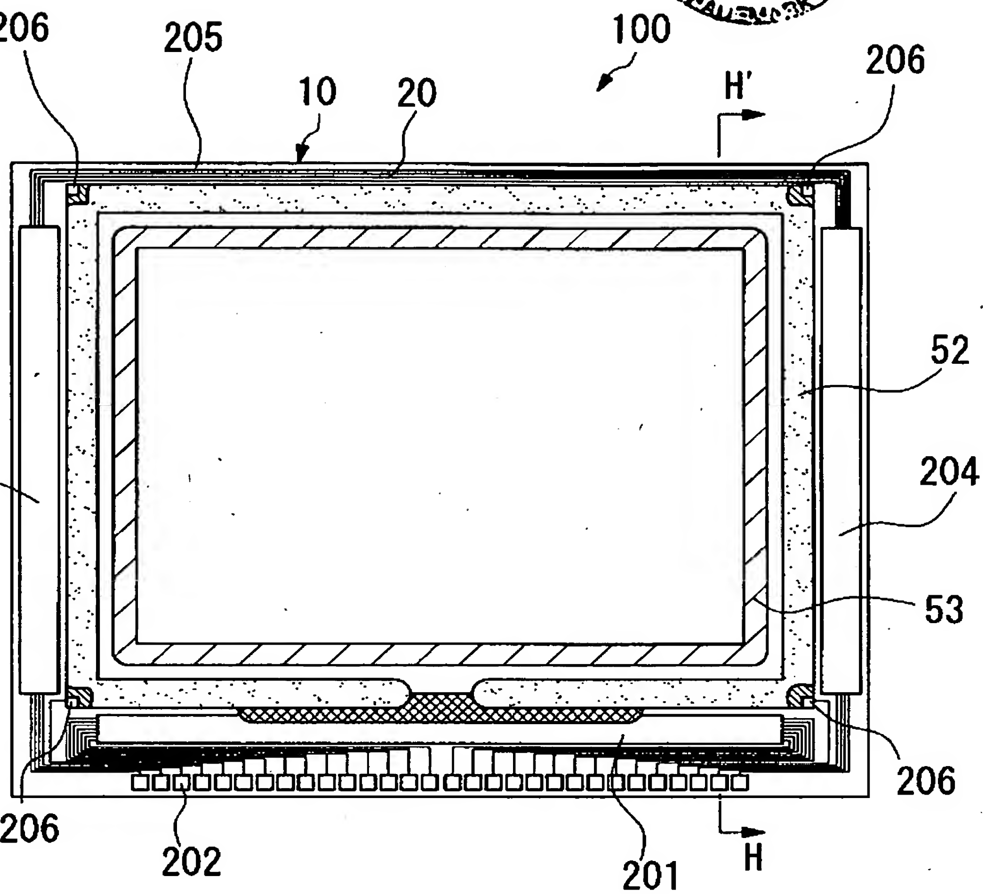
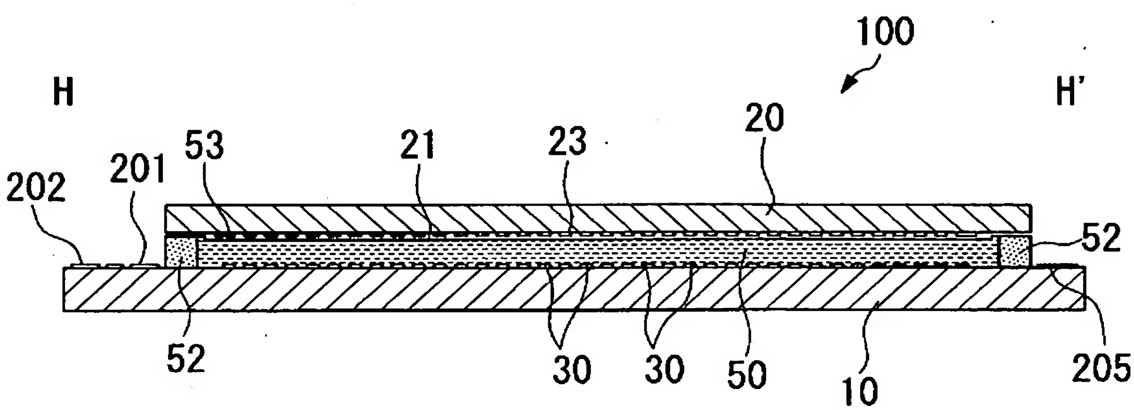

206
205
10
20
100
H'
206
52
204
204
53
206
206
202
201
H

FIG. 2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H
H'
20
202
201
53
21
23
52
52
30
30
50
10
205

FIG. 3

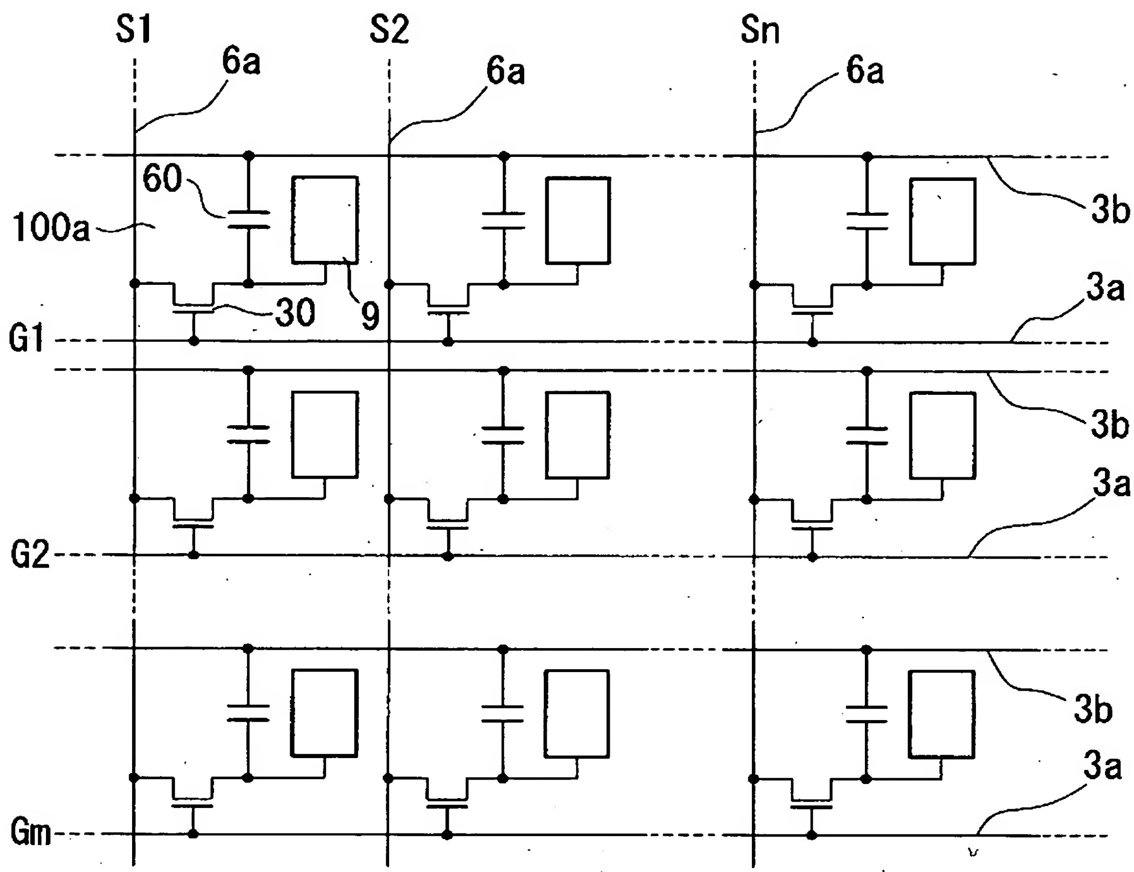


FIG. 4

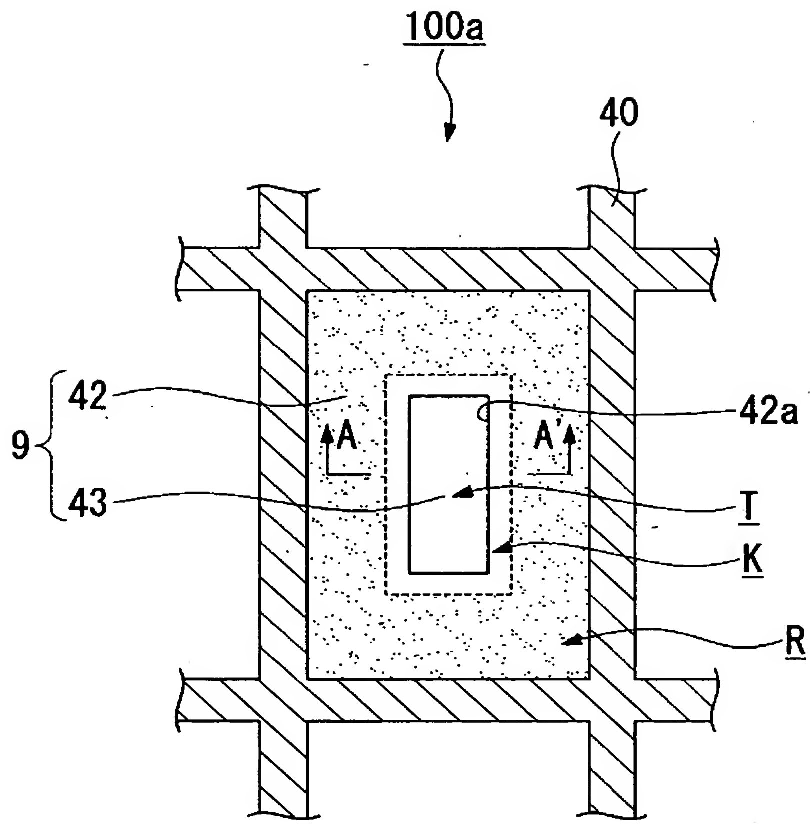
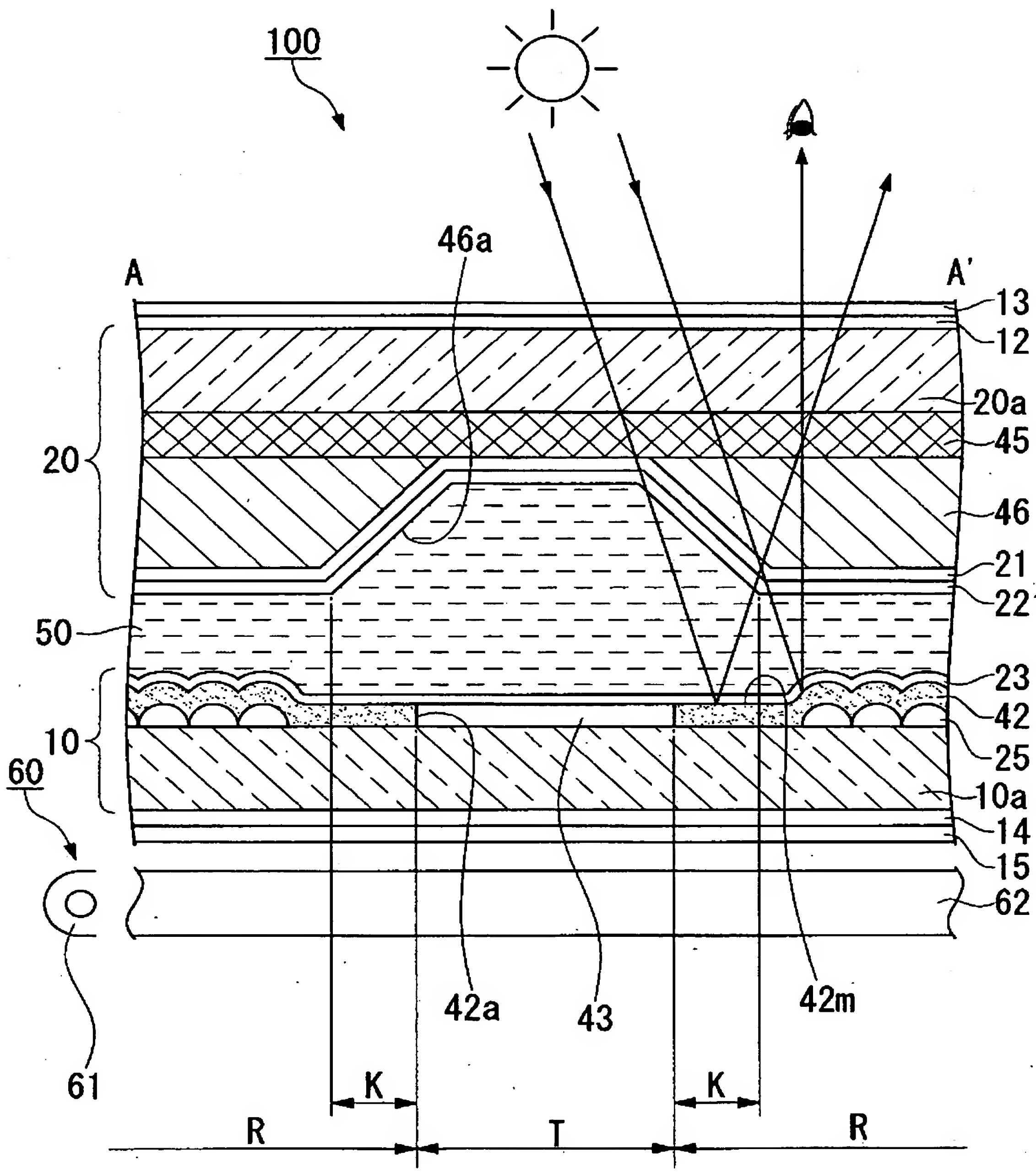


FIG. 5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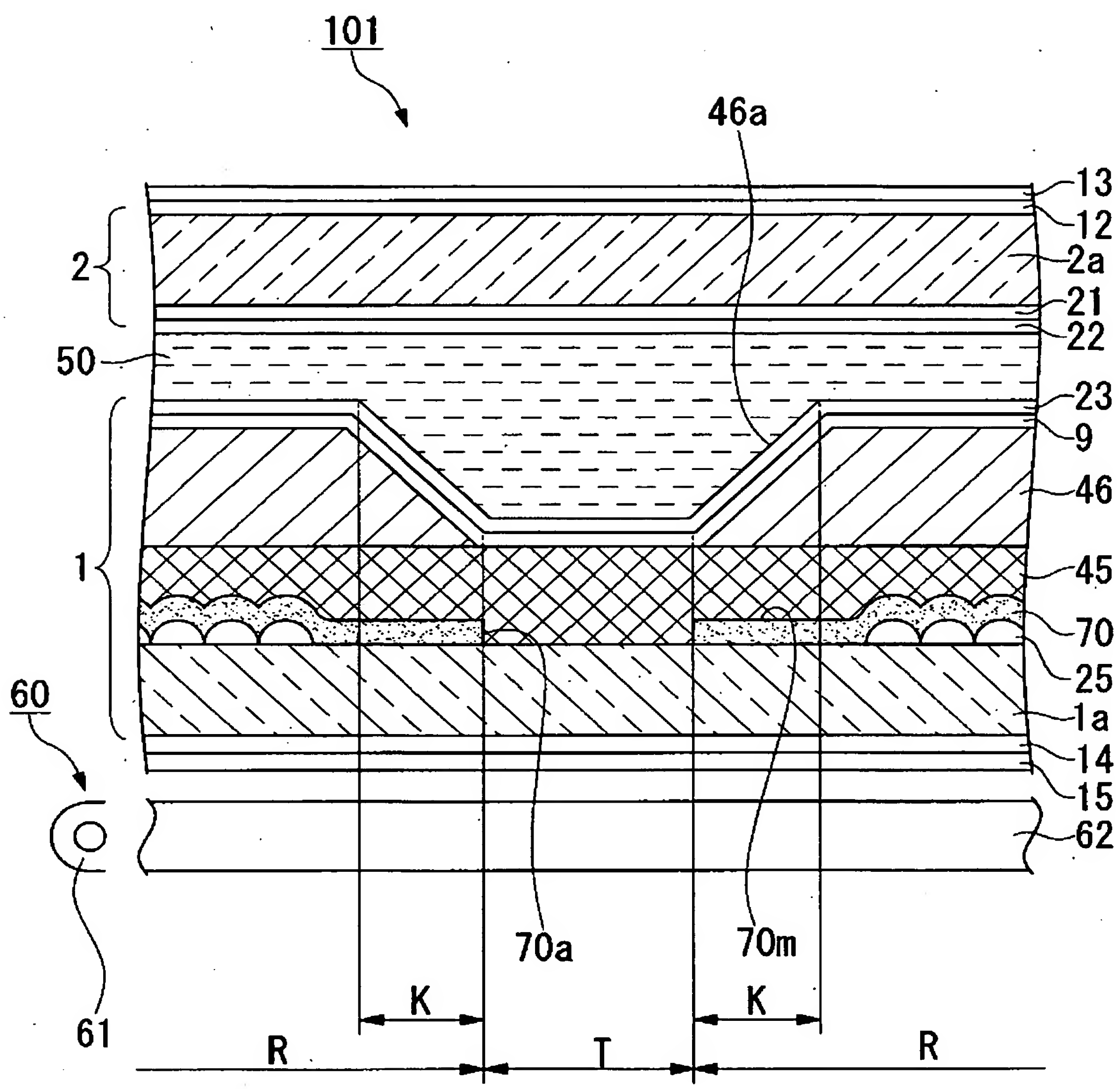
46a
A
A'
13
12
20a
45
46
21
22
20
50
23
42
25
10
10a
14
15
60
62
61
42a
43
42m
K
K
R
T
R

FIG. 6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13
12
2a
2
21
22
50
23
9
46
1
45
70
25
1a
60
14
15
62
61
70a
70m
K
K
R
T
R

FIG. 7

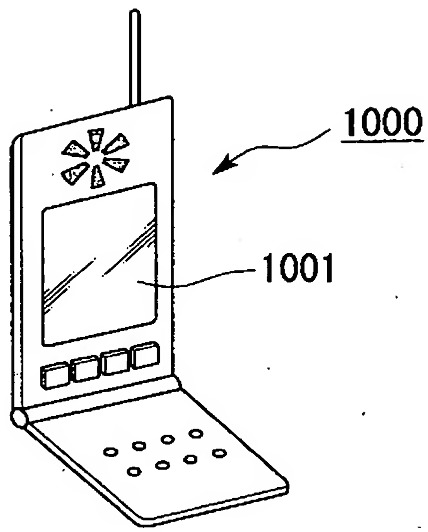

FIG. 8

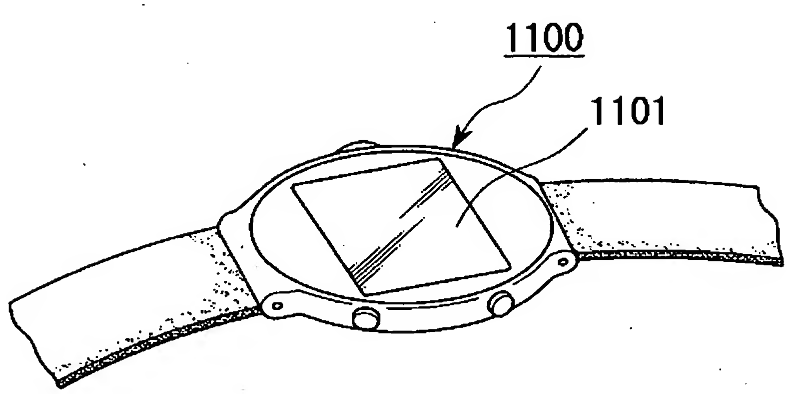

FIG. 9